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HIGH TIME-RESOLUTION STUDIES OF THE AURORAL IONOSPHERE

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SPACE SCIENCES J C FOSTER 01 SEP 84 AFOSR-TR-85-0149

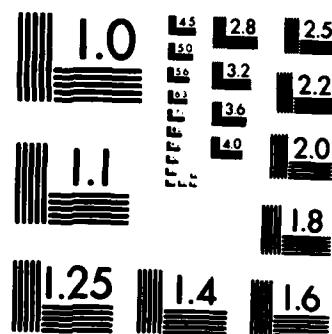
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FINAL REPORT

HIGH TIME RESOLUTION STUDIES OF THE AURORAL IONOSPHERE

Dr. John C. Foster

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## Final Scientific Report for AFOSR-82-0093

## HIGH TIME RESOLUTION STUDIES OF THE AURORAL IONOSPHERE

December 1, 1981 - May 31, 1984

Summary of Activities: AFOSR funding at Utah State University has supported the development of an experimental technique to provide high-resolution radar observations of the spatial structure of the high-latitude ionosphere. Prototype azimuth scanning experiments with the Chatanika, Alaska incoherent scatter radar were combined with analysis software development to permit spatial mapping of ionospheric densities, temperatures, and convection electric fields over a 1000 km radius field of view around the radar. The initial experiments provided details of the spatially complex region near local midnight at auroral latitudes. The technique has been merged with similar analysis efforts developed under AFOS support at Millstone Hill and recently has been applied in coordinated experiments using the Sondrestrom, Greenland and Millstone Hill radars. This grant also supported the participation of the USU Radar Group in the international data analysis program which was part of the multi-radar MITHRAS campaign. Electric field programs developed at Utah State University were used to analyze Chatanika data for inclusion in several multi-instrument studies of the large-scale high-latitude convection pattern. An important MITHRAS goal, that of providing a near simultaneous picture of the electric field pattern in one hemisphere, was realized in these studies. Comparison of the electric field data with ionospheric models was addressed in several ways. An empirical high-latitude convection electric field model was derived from the Chatanika observations and presented in a numerical format for ease of inclusion in ionospheric and magnetospheric mapping simulations. Additional work with the ionospheric modeling project at Utah State University included radar/model comparison studies directed at fine-tuning the model parameters and the provision of graphics for the display of the modeling results. The program initiated under this AFOSR grant has resulted in six refereed publications and is being continued in work at Utah State University and other institutions.

Background of the Research: The Utah State University incoherent scatter radar group made significant contributions to the study of ionospheric electric fields at high latitudes throughout the lifetime of the radar facility at Chatanika. Experimental techniques and analysis procedures for determining the latitudinal variation of the convection electric field with good time resolution had been developed during a sequence of full-day single radar observations. In the course of this work it was determined that the multi-position experimental mode is used at Chatanika (Foster et al., 1981) could not resolve the details of the spatial structure in the electric field pattern near the Harang discontinuity near midnight. Accordingly, a high-resolution electric field mode for monostatic radars was developed. Support for this work was provided by this AFOSR grant. Initial operations took place during the brief remaining lifetime of the Chatanika facility with good results. Details of this work are provided in the following section. In its new location at Sondrestromfjord, Greenland, the operational and analysis procedures developed under this sponsorship promise to bear a rich harvest of detailed new scientific results.

For an interval of approximately one year in 1981-1982 three incoherent scatter radar facilities were equi-spaced around the auroral oval, thus presenting an opportunity for a more detailed investigation of high-latitude

phehomena than had been possible in single-station experiments. In order to coordinate and best utilize this multi-instrument capability, the MITHRAS (de la Beaujardiere et al., 1984) program was proposed to and supported by AFOSR. MITHRAS had as one of its goals the determination of the high-latitude electric field over the combined fields-of-view of the several instruments taking part in the program. At Chatanika, experiments similar to those in use in the USU electric field program were included in the MITHRAS schedule. Although the USU team was not directly involved in the data acquisition portion of MITHRAS, the expertise and software developed in the earlier USU experiments was made available to the MITHRAS analysis program through this grant.

High Time Resolution Studies: The spatial and temporal variability of the high-latitude ionosphere, particularly in the regions of the noon sector cleft and the midnight sector Harang discontinuity, make it difficult to determine details of the convection electric field with a monostatic radar system. Azimuth and elevation scanning experiments can provide detailed maps of the ionospheric densities and temperatures over the field of view of the radar, but the associated line-of-sight velocity maps obtained during such operations require complex analysis procedures to determine the electric field patterns which are responsible for the observed plasma convection. Such experiments and analysis procedures have been in use at Millstone Hill since 1979, but had not been pursued at the Chatanika facility which was situated in the midst of the auroral region. Under AFOSR support data from two experiments at Chatanika were used as test cases to further develop the scanning technique and the related analysis software for close range observations of highly structured ionospheric features. The experiments provided detailed data on the midnight sector of the auroral oval, including the region of plasma convection out of the polar cap near the Harang discontinuity. Patches of high density F region plasma were observed to be convected equatorward out of the night sector polar cap from whence they were caught up in the sunward convective flow away from midnight at auroral latitudes. Observations of a narrow, deep density trough aligned with the direction of the convective flow were interpreted in terms of ionospheric plasma transport driven by magnetospheric processes. Details of these phenomena are presented in Foster (1984) and Figure 1 presents an example of the high-resolution spatial mapping achieved with the technique. A further publication will describe the complete set of night sector observations and concludes that whereas the convection pattern can be uniform over several thousand kilometers longitudinal extent at dusk and dawn, the effects of equatorward transport from polar latitudes dominate the observations near midnight. In the course of this work several useful data display techniques were developed including an improved contrast gray scale for presenting the data maps in a readily reproducible format.

The azimuth scanning experiment and analysis techniques developed at Chatanika have been used to investigate the complex ionospheric features in the vicinity of the dayside cleft in experiments with the Sondrestrom radar. This work, although not directly supported by AFOSR, follows directly from the development work supported by this grant. In the following example the experiment developed under this support has been run at Sondrestrom and the analysis procedure, including the enhanced gray scale, implemented at Millstone Hill. Figure 2 presents a spatial mapping of the F region density perturbations produced by parallel bands of soft (<1 kev) electron precipitation in the noon sector. Data from a complete 360 degree azimuth scan are shown as if looking down on the field of view from above. Parallel bands of enhanced ionization extending from 150 to 350 km altitude were seen at this time. Contours of the electrostatic potential (plasma convection streamlines) derived from the high-resolution line-of-sight velocity observations during the scan are shown superimposed on the density data. The precipitation features are aligned with

the poleward edge of the region of strong westward (sunward) convection in the post-noon ionosphere. Details of this experiment at Sondrestrom are presented by Foster et al. (1984).

MITHRAS Analysis: The Utah State University contribution to the MITHRAS analysis program supported by this grant centered on our area of expertise, the high-latitude convection electric field. Procedures for calculating the pattern of ionospheric electrostatic potential from multi-position radar observations had been developed by Foster et al. (1982) and these were used in the analysis of similar data sets acquired at Chatanika during the MITHRAS program. In the study of the temporal evolution of the large-scale high-latitude potential pattern by Heelis et al. (1983) it was found that a highly asymmetric two-cell pattern developed during an IMF AWAY interval. This study combined the analysis procedures developed for Chatanika, Millstone Hill, and the AE satellite. The Chatanika potential analysis was also included in the substorm study of de la Beaujardiere et al. (1983).

A goal of the MITHRAS program is the utilization of the detailed radar observations in predictive ionospheric models. Under the support of this grant an empirical auroral convection electric field model was developed from Chatanika observations as reported by Foster (1983). Figure 3, taken from that work, presents details of the model. The ionospheric electric field, and the resultant plasma convection, is intimately related to processes which drive the circulation of plasma within the magnetosphere. This aspect of the radar observations has been addressed in the work of Sojka et al. (1983a) who mapped the ionospheric electric field model of Foster (1983) into the magnetosphere. Foster (1984) further discussed the implications of the ionospheric radar observations for understanding the magnetospheric processes. Under this grant the MITHRAS collaboration with the ionospheric modeling group at Utah State University was begun. This association has resulted in the initial model/radar comparison study of Sojka et al. (1983b) and is being continued in additional studies.

Publications: The following scientific publications directly resulted from work supported by this AFOSR grant.

An Empirical Electric Field Model Derived from Chatanika Radar Data, J. C. Foster, J. Geophys. Res., 88, 981, 1983.

Mapping the Electrostatic Potentials from the Ionosphere to the Magnetosphere, J. J. Sojka, J. C. Foster, P. M. Banks, and J. R. Doupinik, Planet. Space Sci., 31, 1329, 1983a.

Multistation Measurements of High-Latitude Ionospheric Convection, R. A. Heelis, J. C. Foster, O. de la Beaujardiere, and J. Holt, J. Geophys. Res., 88, 10111, 1983.

Ionospheric Signatures of Magnetospheric Convection, J. C. Foster, J. Geophys. Res., 89, 855, 1984.

MITHRAS: A Brief Report, O. de la Beaujardiere et al., Radio Science, 19, 665, 1984.

High-Resolution Observations of Electric Fields and F region Plasma Parameters in the Cleft Ionosphere, J. C. Foster, J. M. Holt, J. D. Kelly, and V. B. Wickwar, in Proceedings of NATO Advanced Workshop on the Morphology and Dynamics of the Polar Cusp, J. Holtet, ed., D. Reidel, Dordrecht, in press, 1984.

Other published work referenced in this final scientific report:

Early MITHRAS Results: The Electric Field Response to Substorms, O. de la Beaujardiere, J. Holt, and E. Nielsen, Radio Science, 18, 981, 1983.

Large-scale Patterns of Auroral Ionospheric Convection Observed with the Chatanika Radar, J. C. Foster, G. S. Stiles, and J. R. Douphnik, J. Geophys. Res., 11357, 1981.

Electrostatic Potential in the Auroral Ionosphere derived from Chatanika Radar Observations, J. C. Foster, P. M. Banks, and J. R. Douphnik, J. Geophys. Res., 87, 7513, 1982.

Comparison of Model High-Latitude Electron Densities with Millstone Hill Observations, J. J. Sojka, R. W. Schunk, J. V. Evans, J. M. Holt, and R. H. Wand, J. Geophys. Res., 88, 7783, 1983b.

Professional Personnel: Direct support was provided by this grant for the following senior personnel:

John C. Foster	Principal Investigator Research Associate Professor, Utah State University
Joe R. Douphnik	Co-Principal Investigator Professor, Utah State University

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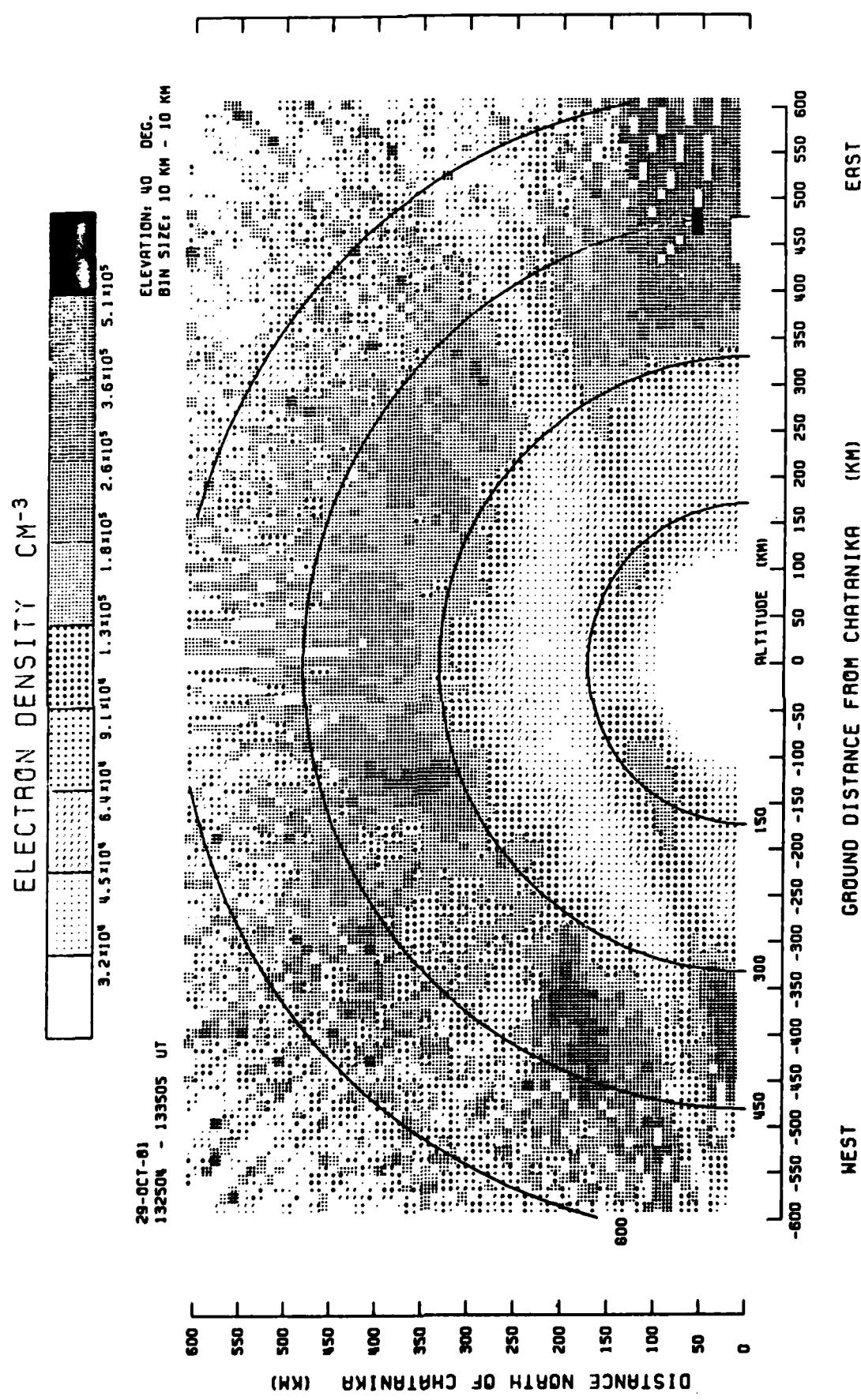


Figure 1. Chatanika Radar observation of a narrow ( $50 \text{ km}$ ) F region trough aligned along the sunward direction of convection near dawn. Altitude increases away from the centrally located radar in this azimuth scan data presentation. The trough extends over  $1200 \text{ km}$  in the east-west direction and was observed for over 4 hours. (From Foster, 1984)

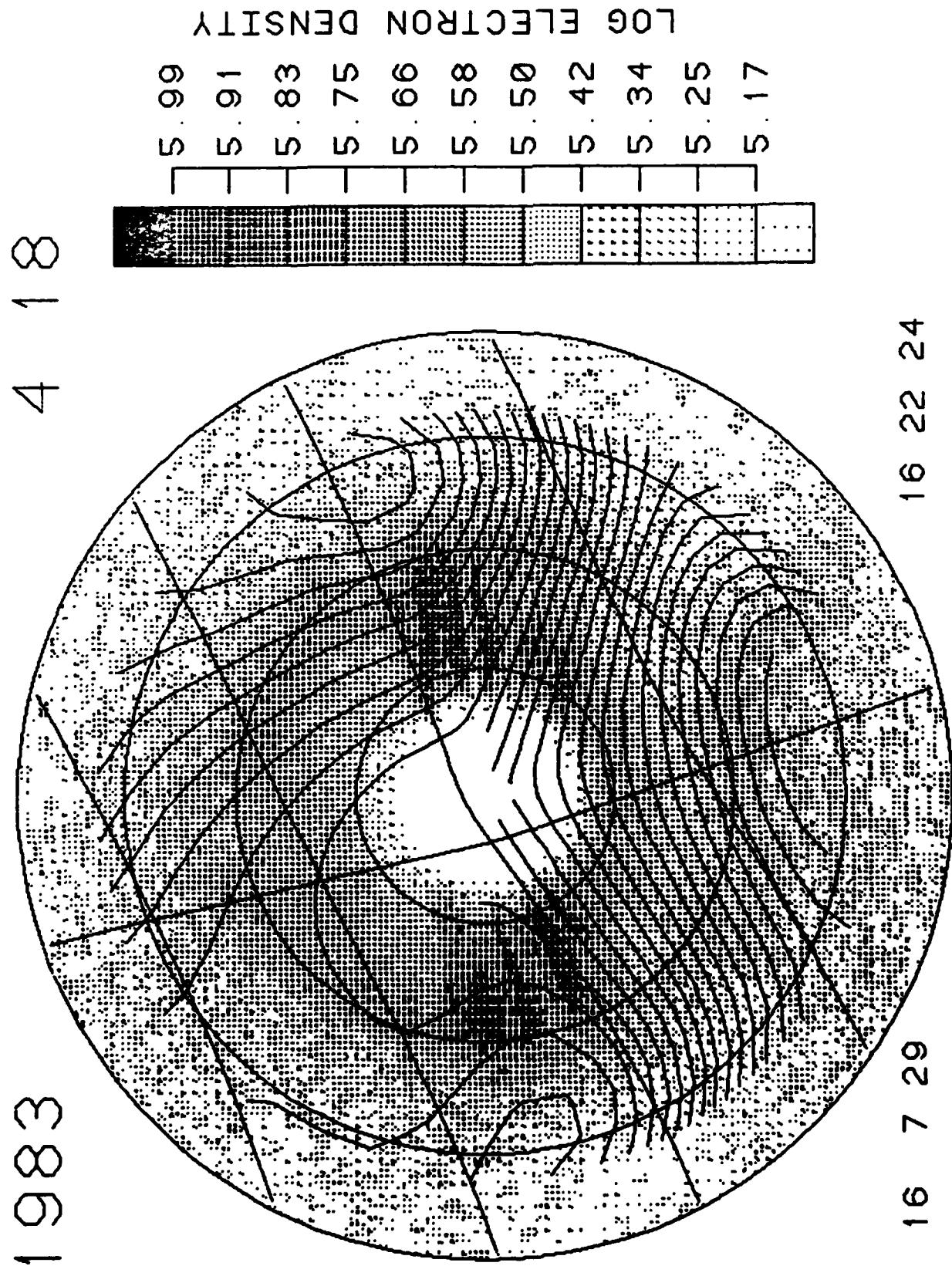
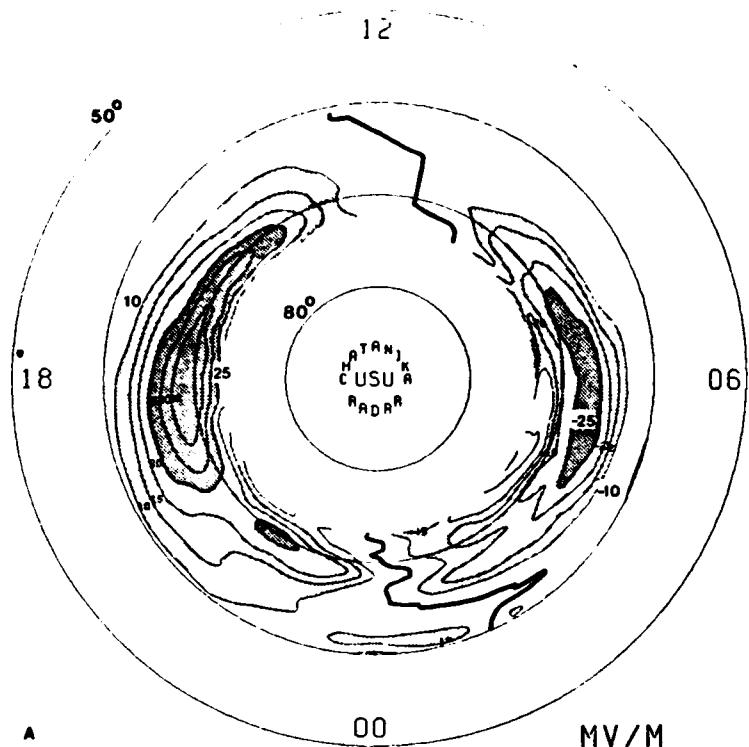
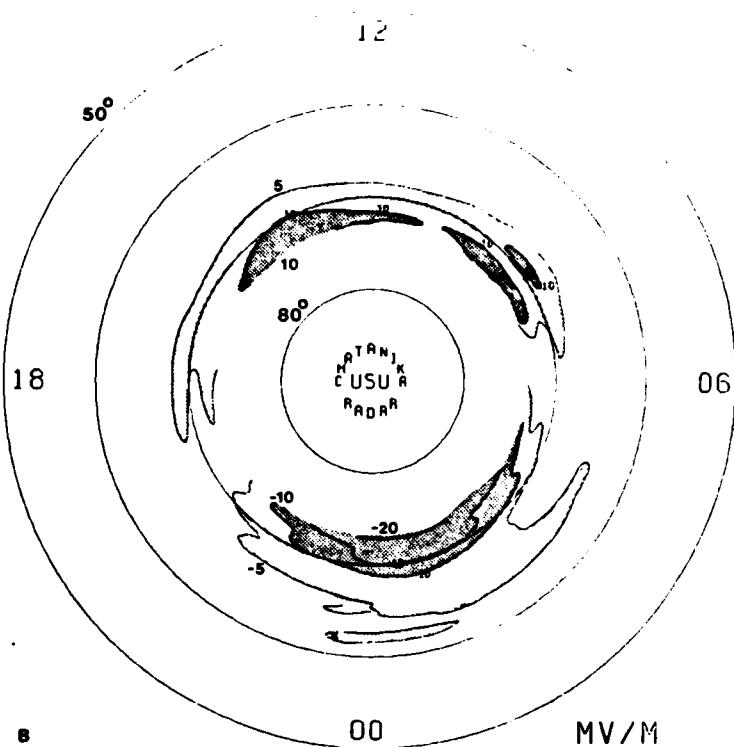


Figure 2. High-spatial resolution plasma density observations observed over a 1000 km diameter field of view from Sondrestrom 1 hour after local noon. Constant altitude circles are shown at 150 km intervals. North is at the top of the figure. Precipitation-enhanced plasma density was observed as narrow east-west aligned bands at the poleward edge of the post-noon region of sunward convection. Contours of constant electrostatic potential (plasma flow streamlines) are superimposed over the density data at 2 kV spacing. (From Poster et al., 1984)

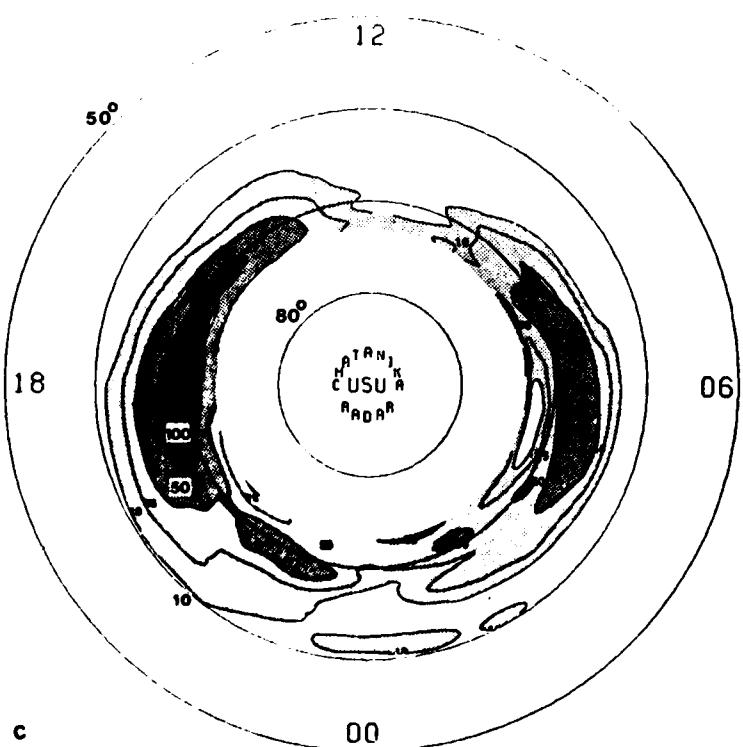
## NORTHWARD ELECTRIC FIELD



## EASTWARD ELECTRIC FIELD



## SQUARED ELECTRIC FIELD



## ELECTROSTATIC POTENTIAL

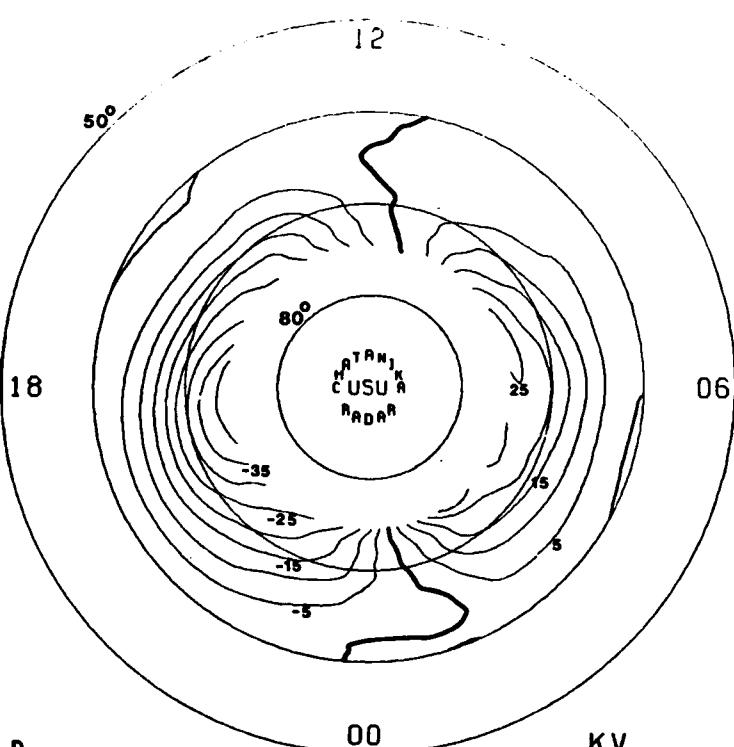


Figure 3. The electric field model of Foster (1983) which was derived from 10 days data observed during moderately disturbed summer condition with the Chatanika radar.

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